

## WAVEGUIDES AND BACKPLANE SYSTEMS

### Cross-Reference to Related Applications

This application is a division of U.S. Patent Application Serial No. 09/429,812, filed October 29, 1999, the contents of which are hereby incorporated herein 5 by reference.

### Field of the Invention

This invention relates to waveguides and backplane systems. More particularly, the invention relates to broadband microwave modem waveguide backplane systems.

### 10 Background of the Invention

The need for increased system bandwidth for broadband data transmission rates in telecommunications and data communications backplane systems has led to several general technical solutions. A first solution has been to increase the density of moderate speed parallel bus structures. Another solution has focused on relatively less 15 dense, high data rate differential pair channels. These solutions have yielded still another solution - the all cable backplanes that are currently used in some data communications applications. Each of these solutions, however, suffers from bandwidth limitations imposed by conductor and printed circuit board (PCB) or cable dielectric losses.

The Shannon-Hartley Theorem provides that, for any given broadband data

transmission system protocol, there is usually a linear relationship between the desired system data rate (in Gigabits/sec) and the required system 3dB bandwidth (in Gigahertz). For example, using fiber channel protocol, the available data rate is approximately four times the 3 dB system bandwidth. It should be understood that bandwidth considerations 5 related to attenuation are usually referenced to the so-called "3dB bandwidth."

Traditional broadband data transmission with bandwidth requirements on the order of Gigahertz generally use a data modulated microwave carrier in a "pipe" waveguide as the physical data channel because such waveguides have lower attenuation than comparable cables or PCB's. This type of data channel can be thought of as a 10 "broadband microwave modem" data transmission system in comparison to the broadband digital data transmission commonly used on PCB backplane systems. The present invention extends conventional, air-filled, rectangular waveguides to a backplane system. These waveguides are described in detail below.

Another type of microwave waveguide structure that can be used as a 15 backplane data channel is the non-radiative dielectric (NRD) waveguide operating in the transverse electric 1,0 (TE 1,0) mode. The TE 1,0 NRD waveguide structure can be incorporated into a PCB type backplane bus system. This embodiment is also described in detail in below. Such broadband microwave modem waveguide backplane systems have superior bandwidth and bandwidth-density characteristics relative to the lowest loss 20 conventional PCB or cable backplane systems.

An additional advantage of the microwave modem data transmission system is that the data rate per modulated symbol rate can be multiplied many fold by data compression techniques and enhanced modulation techniques such as K-bit quadrature amplitude modulation (QAM), where K=16, 32, 64, *etc.* It should be understood that, with 25 modems (such as telephone modems, for example), the data rate can be increased almost a hundred-fold over the physical bandwidth limits of so-called "twisted pair" telephone lines.

Waveguides have the best transmission characteristics among many transmission lines, because they have no electromagnetic radiation and relatively low 30 attenuation. Waveguides, however, are impractical for circuit boards and packages for two

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major reasons. First, the size is typically too large for a transmission line to be embedded in circuit boards. Second, waveguides must be surrounded by metal walls. Vertical metal walls cannot be manufactured easily by lamination techniques, a standard fabrication technique for circuit boards or packages. Thus, there is a need in the art for a broadband 5 microwave modem waveguide backplane systems for laminated printed circuit boards.

### **Summary of the Invention**

A waveguide according to the present invention comprises a first conductive channel disposed along a waveguide axis, and a second conductive channel disposed generally parallel to the first channel. A gap is defined between the first and 10 second channels along the waveguide axis. The gap has a gap width that allows propagation along the waveguide axis of electromagnetic waves in a TE  $n,0$  mode, wherein  $n$  is an odd number, but suppresses electromagnetic waves in a TE  $m,0$  mode, wherein  $m$  is an even number.

Each channel can have an upper broadwall, a lower broadwall opposite and 15 generally parallel to the upper broadwall, and a sidewall generally perpendicular to and connected to the broadwalls. The upper broadwall of the first channel and the upper broadwall of the second channel are generally coplanar, and the gap is defined between the upper broadwall of the first channel and the upper broadwall of the second channel. Similarly, the lower broadwall of the first channel and the lower broadwall of the second 20 channel are generally coplanar, and a second gap is defined between the lower broadwall of the first channel and the lower broadwall of the second channel. Thus, the first channel can have a generally C-shaped, or generally I-shaped cross-section along the waveguide axis, and can be formed by bending a sheet electrically conductive material.

In another aspect of the invention, an NRD waveguide having a gap in its 25 conductor for mode suppression, comprises an upper conductive plate and a lower conductive plate, with a dielectric channel disposed along a waveguide axis between the conductive plates. A second channel is disposed along the waveguide axis adjacent to the dielectric channel between the conductive plates. The upper conductive plate has a gap along the waveguide axis above the dielectric channel. The gap has a gap width that